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DUAL BAND FRACTAL ANTENNA

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ABSTRACT

A fractal antenna with dual band characteristics has been designed and presented in this paper. The fractal antenna is found to be resonant at 2.33 GHz and 6.58 GHz. This antenna is compact compared to conventional square antenna of same size. The antenna is realized on low cost FR4 material. The antenna has improved impedance bandwidth. The radiation patterns of this antenna at both the resonant frequencies are found to be nearly omni directional in azimuth plane at 90 degree elevation angle. The fractal antenna is useful in multiband wireless communication.

KEYWORDS: Compact, Antenna, Fractal, Multiband, Broadband

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Original Article

INTRODUCTION

With the advances in wireless technology to exploit variety of applications, multiband antennas or wideband antenna have been widely studied [1]-[3]. The bandwidth requirement of Doordarshan (television) in India, around 1985 was only to exploit 1 0r 2 channels whereas this bandwidth requirement has been increased to many fold in 2015-16 requiring at least 200 channels to be received using a single antenna. Now days, with advanced wireless techniques these channels are required to be available at many miniaturized wireless devices such As laptops, tablets, cell phones etc. This necessary put constraints on the size of antenna to keep these gadgets to be compact in size. The antennas are required to be small in size with enhanced bandwidth or multiband nature and necessary gain characteristics. The various wireless applications those are popular now days are listed in Table1.

Table 1: Frequency Bands for a Few Popular Wireless Applications [1]-[3]

Wireless Applications	Frequency Band (MHz)
2G	800/900 1800/1900
3G	1800-2500
4G	2000-8000
Wireless Communication Service	2305-2320 / 2345-2360
Satellite Digital Radio	2320-2680
Multichannel Multipoint Distribution Service (MMDS)	2150-2680
GPS	1570.42-1580.42
DCS – 1800	1710-1880
PCS – 1900	1850-1990
IMT-200 / UMTS	1885-2200
ISM Band I (Cordless Phone 1G WLAN)	902-928
ISM Band II (Bluetooth 802.11b WLAN)	2400-2483.5
Lower LTE (long term evolution) bands	790–960
Upper LTE bands	1710–269

The telecommunications systems has been widely exploited using wireless local area network [1]-[4]. Fractal antennas are found useful to exploit multiband compact wireless communication services [1]-[4]. In 1975, the father of fractal Mandelbrot has given the definition of fractal to be a fragmented or broken structure that can be differentiated into parts which remains a reduced size copy of the whole [5],[9]-[10]. Also, Mandelbrot has invented many naturally occurring fractals those cannot be defined by conventional Euclidean geometry [10]. One can differentiate between fractal and Euclidean geometry as suggested in Table 2. Some of the example of naturally occurring fractals are lightning, ameba, trees, snowflake etc.

Table 2: Difference between Fractal and Euclidean Geometry [10] Fractal Euclidean

Fractal	Euclidean
Often defined by iterative rule	Often defined by formula
Structure on many scales	Structure on one or few scales
Dilation symmetry (self similarity)	No self similarity
Fractional dimension possible	Integer dimension
Long range correlation	Variable correlation
Described as ramified, variegated, spiky	Described as regular
Rough on most scales	Smooth on most scales

Several naturally occurring phenomena such as lightning are better analyzed with the aid of fractals. Mandelbrot defines the term fractal based on the definition of their dimension such as topological dimension, Euclidean dimension, self-similarity dimension and Hausdorff dimension [5], [9]. Fractal is defined as set F such that [5]: F has a fine structure with details on indiscriminately small scales, F is too irregular to be described by traditional geometry. F having some form of self-similarity (not necessarily geometric, can be statistical), F can be described in a simple way, recursively, and fractal dimension of F is greater than its topological dimension. The most simple definition fractal dimension for self-similarity fractals is given by,

$$D = (\log n) / \log (1/f) \tag{1}$$

Where, n-no. of self-similar copies and f- fractional scale. Fractal geometries are generally infinitely sub-divisible. Other properties associated with fractal geometries include scale invariance, plane filling or space-filling nature, and lacunarity [10]. Some of these properties can be qualitatively linked to the features of antenna geometries using them.

A fractal often has applications in antennas for multiband wireless communication, image processing for data compression, packaging, mechanics (fracture mechanics is a widely studied subject by mechanical engineers) etc. The use of self similarity property in fractal antennas can achieve multiband characteristics whereas space filling property in these antennas can be used for miniaturization. Fractal antennas have been reported for compact, multiband and broadband applications [1], [6-7], [8], [10]. Although fractals can be used for compact antenna applications they need to obey the fundamental limit for compactness studied by Wheeler, Chu and McLean [11]-[13] etc given by (2),

$Q_{rad} = [1/ (ka)^3] + [1/ ka]$ Collin, McLean, Chu(exact)

$= (1+ 2(ka)^2) / [(ka)^3 (1+ 2(ka)^2]$ Chu (approximate)

$= [1/ (ka)^3]$ using Geometric mean by VA Tech. (2)

where, k - the wave number associated with the electromagnetic field,

a-the radius of the sphere enclosing the antenna,

Q_{rad} - radiation quality factor antenna. This fundamental limit is must in small or compact antennas to avoid degraded performance.

In this paper presents the design and analysis of the conventional square patch antenna geometry has been modified to behave as compact and dual-band fractal antenna using iterative fractal technique.

DESIGN OF ANTENNA

The proposed antenna hardware has been designed on FR4 substrate of area 625 square millimeter with thickness (h) 1.56 mm and dielectric constant (ε_r) 4.3. First, the square patch of the size 529 square millimeter has been realized on this substrate using dimensions, L (length) = W (width) = 23 mm. The substrate is backed by the ground i.e. a copper material of size 625 sq. m. The design of such conventional antenna is shown in Figure 1.

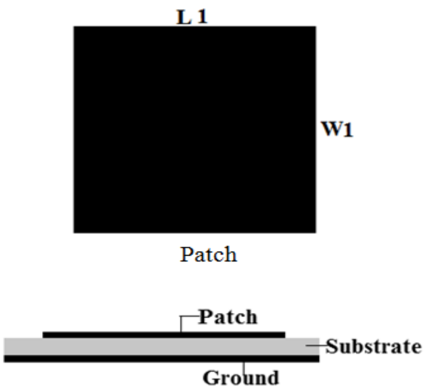


Figure 1: Design of Conventional Antenna

Now, the proposed fractal antenna as shown in Figure 2 is realized on the substrate by generating a slot of dimension L = W = 13.861 mm in the conventional square patch of dimensions, L = W = 23 mm. An another square patch of dimensions, L = W = 9.351 mm with a gap of 4.5 mm from inner boundary first slotted patch or external boundary of first slot is generated as shown in Figure 2.

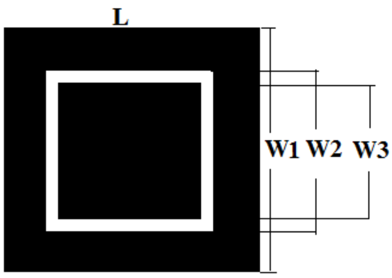


Figure 2: Design of First Iterated Fractal Antenna

RESULTS AND DISCUSSIONS

The conventional and the proposed fractal antennas are compared using their reflection loss characteristics as shown in Figure 3. It can be easily understood that although the size of both conventional and fractal antenna are same, but the realized resonant frequency of 2.33 GHz using proposed fractal antenna is found to be much lower than 2.98 GHz

realized using a conventional patch of same size. This is due to increase in the length of current path (L) due to incorporation of slot to reduce the size of the antenna to attribute compactness in the proposed antenna.

The measured and simulated reflection loss characteristics of the conventional antenna are in close agreement as shown in Figure 3 and are tabulated in Table 3.

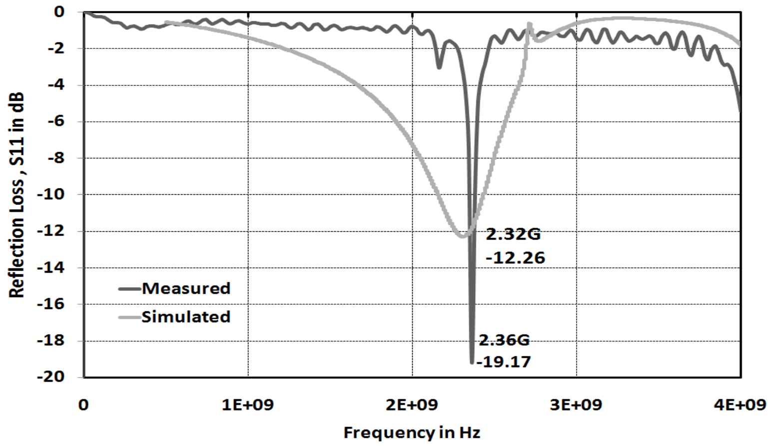


Figure 3: Simulated and Measured Reflection Loss for First Iterated Fractal Antenna

Fractal antennas are in close agreement. As shown in Figure 2, the proposed fractal antenna has two square patches separated by a gap to represent dual band properties. Therefore the proposed fractal antenna shows 2.33 GHz and 6.58 GHz frequencies. First due to larger patch size and second due to smaller patch size as shown in Figure 4.

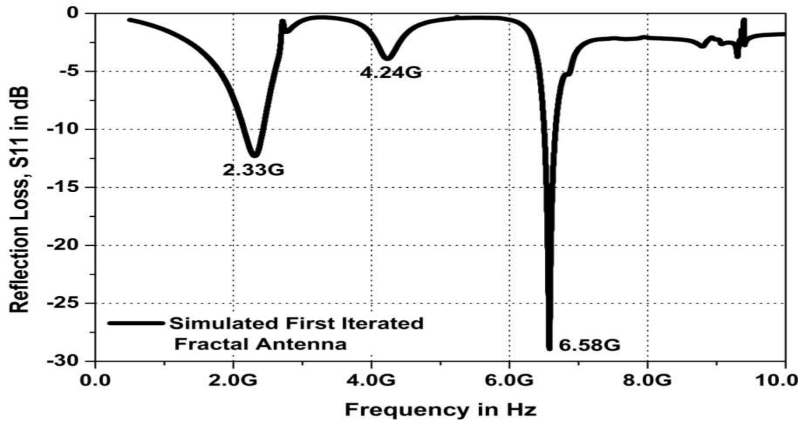


Figure 4: Simulated Reflection Loss Plot First Iterated Fractal Antenna

In addition to these two resonance frequencies, a spurious second resonance is observed between these two resonances due to outer square ring. All the results are shown in Table 3.

Table 3: Comparative Reflection Loss of Various Configurations of Antenna

Types of Antenna	Simulated, S_{11}	Measured, S_{11}
Square patch antenna	3 GHz, -21.52 dB	2.98 GHz, -11.17 dB
1st Iterated fractal antenna	2.33 GHz, 6.58 GHz,	2.36 GHz,

The empirical formulation to justify the realized frequencies and dual bend nature of the antenna is reported in [3] and given by equation (3) and (4) below and can be used to design the dual band antenna for desired frequency band.

$$f_1 = c / 2 (\sqrt{\varepsilon_{eff}}) * L' \quad (3)$$

$$f_2 = c / 2 (\sqrt{\varepsilon_{eff}}) * L'' \quad (4)$$

Here, L' = L + W2 = 36. 861 mm and L'' = √2 * W3 = 13.224 mm. L' and L'' are average lengths of the current paths for first & second resonance and L = 23 mm, W2 = 13.861mm and W3 = 9.351 mm are physical dimensions.

The conventional and fractal antennas are compared on the basis of their impedances and are shown in Figure 5 and 6 respectively. The dual band characteristics of the fractal antenna can also be seen in their impedance characteristics as shown in Figure 6. Both, the antennas are found to be resonant where the impedance of the excitation is 50 Ω to find a good impedance matching.

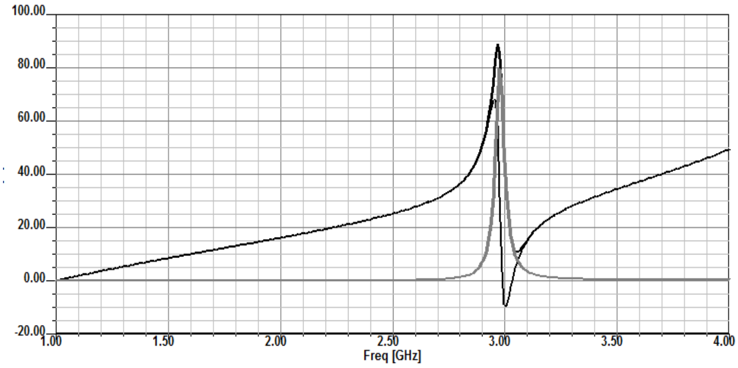


Figure 5: Real and Imaginary Part in Impedance Exhibited by Conventional Square Patch Antenna

It is seen in Figure 6 and 7 that reactance of the antenna is minimum near the resonance to reduce the stored reactive power to exhibit maximum radiative nature.

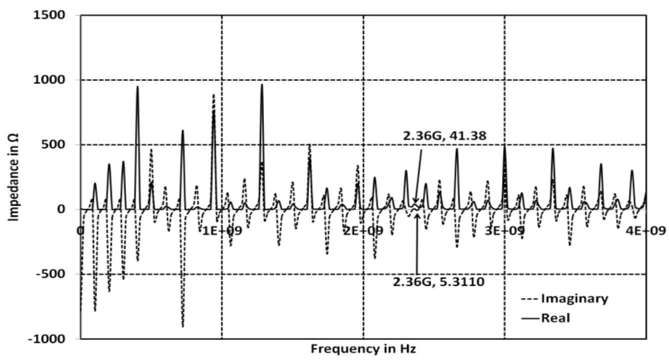
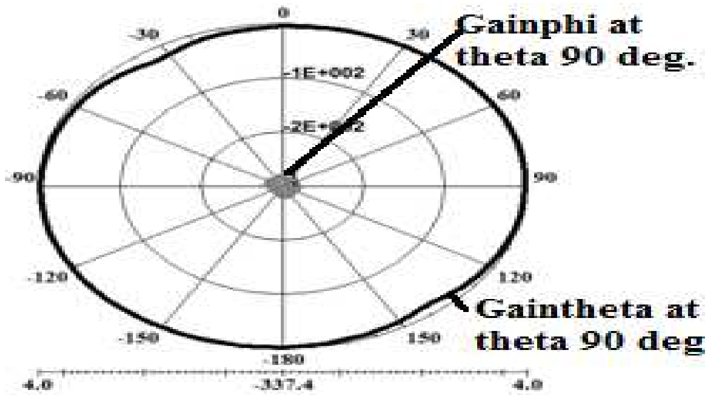


Figure 6: Real and Imaginary Part in Impedance Exhibited by 1st Iteration Fractal Square Patch Antenna

RADIATION PATTERNS

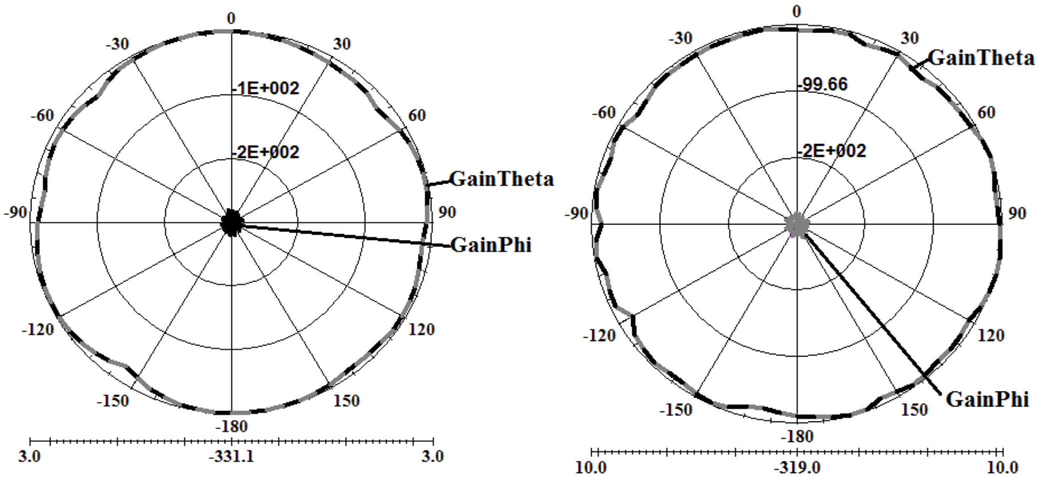
The gain theta and gain phi radiation patterns of the conventional and fractal antenna at resonating frequencies have been simulated as shown in Figure 7 and 8. It has been seen that the fractal antenna shows similar and omni directional radiation pattern in azimuth plane at 90 degree elevation. The theta-gain of 4 dB at 2.99 GHz at elevation angle equal to 90 degree in conventional antenna is observed compared to 3 dB and 10 dB at 2.33 GHz and 6.58 GHz respectively in the

proposed first iterated fractal antenna as shown in Figure 2.



H-plane

Figure 7: Radiation Patterns for Conventional Square Patch Antenna at 2.99 GHz



At theta 90 deg.
f = 2.33 GHz

At theta 90 deg.
f = 6.58 GHz

Figure 8: Radiation Patterns for 1st Iteration Fractal Antenna in H Planes

CONCLUSIONS

The proposed fractal has shown dual band characteristics due to self-similar patches. Incorporation of self similarity in the proposed fractal design not only made the antenna multiband but has represented the compactness by reducing the dimension required to realize the lowest frequency in the antenna using a conventional square patch antenna. The square fractal patch antenna shows dual band behavior due to two self similar iterations incorporated in the designed antenna compared to its conventional counterparts. This compactness is attributed to space filling properties in the antenna. The antenna is found useful to exploit many wireless applications requiring multiple wireless frequency bands.

REFERENCES

1. *J. Kim, C. Yang, T. Yun, and C. Jung, "Multimode Multiband (VHF / UHF /L / 802.11 a/b) Antennas for Broadcasting and Telecommunication Services", IEEE Antennas and Wireless Propagation Letters, Vol. 10, 2011.*

2. *Cheng-Hung Kang, Sung-Jung Wu, and Jenn-Hwan Tarng, "A Novel Folded UWB Antenna for Wireless Body Area Network", IEEE Transactions on Antennas and Propagation, Vol. 60, No. 2, February 2012.*
3. *Homayoon Oraizi and Shahram Hedayati, "Circularly Polarized Multiband Microstrip Antenna Using the Square and Giuseppe Peano Fractals", IEEE Transactions On Antennas and Propogation, Vol. 60, No. 7, July 2012.*
4. *A. Goldsmith, "Wireless Communications", Chapter1- Overview of Wireless Communications, Cambridge University Press.*
5. *Balanis, Antenna Theory and Analysis, John Wiley publications.*
6. *Hattan F. Abutarboush et al., "A Reconfigurable Wideband and Multiband Antenna Using Dual-Patch Elements for Compact Wireless Devices", IEEE Antennas and Wireless Propagation Letters, Vol. 8, 2009.*
7. *Leonardo Lizzi, Federico Viani, Edoardo Zeni, and Andrea Massa, "A DVBH/GSM/UMTS Planar Antenna for Multimode Wireless Devices", IEEE Transactions on Antennas and Propagation, Vol. 60, No. 1, January 2012.*
8. *Fong Chen et al.,"Bowtie-Feed Broadband Monopole Antenna for Laptop Applications", IEEE Antennas and Wireless Propagation Letters, Vol. 10, 2011.*
9. *B. B. Mandelbrot, The Fractal Geometry of Nature, New York: W. H. Freeman, (1983).*
10. *D. H. Werner, Raj Mitra, Frontiers in Electromagnetics, IEEE Press Series on Microwave Technology and RF.*
11. *H. A. Wheeler, "Fundamental Limitations of Small Antennas", Proc. IRE Vol. 35, 1479-1484, Dec. (1947).*
12. *L. J. Chu, "Physical Limitations on Omni-Directional Antennas", J. Appl. Phys., Vol. 19, 1163-1175, Dec. (1948).*
13. *E. D. Caswell, W. A. Davis, and W. L. Stutzman, "Fundamental Limits on Antenna Size", IEEE Transaction on Antennas and Propagation, (2000).*